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The Growth of Radish Seedlings in Nutrient Solutions

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THE GROWTH OF RADISH SEEDLINGS IN NUTRIENT SOLUTIONS

BY

REED OSHEA BRIGHAM

B. S. (Hort.) Ohio State University, 1912

THESIS

Submitted in Partial Fulfillment of the Requirements for the Degree of

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Reed Oshea Brigham

ENTITLED THE GROWTH OF RADISH SEEDLINGS IN NUTRIENT SOLUTIONS

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

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Introduction

Dr. Emil Godlewski (3 &4) in his research studies on light relations and the growth of plants, found that young radish seedlings grown in distilled water developed poorly, and it became apparent that in the growth of the seedling the mineral matter was of great significance both in the light and in the dark. His cheif interest was however with the light relations and he did not carry out any work on the effect of the mineral salts.

The literature bearing directly upon the influence of mineral salts on growth of seedlings is very limited. W. J. V. Osterhout (14, 15, 16) in his extensive studies on balanced physiological solutions has found much of importance. He found that a disproportionate relation of the mineral salts caused them to act as a poison. Schreiner, Oswald, and Skinner (19) have done some work upon the proper ratio of phosphates, nitrates and of potassium salts on absorption and growth. Loew (10) has given us some important conclusions in the relation between calcium and magnesium.

Following some of the suggestions of previous workers I began a study of the growth of seedlings of four different varieties of radishes, in distilled water, and in solutions of varying combinations and concentrations of salts, and under different temperature and light relations. The following is a record of my results on the radish seedlings.

Acknowledgement

Grateful acknowledgement is hereby made to Professor Charles F. Hottes, who suggested this problem to me, and under whose direction and assistance I carried out the experiment and prepared this thesis.

Methods

The experiments herein described were carried on with the following four varieties of Dreer's radishes, namely, Round Red Forcing, Dreer's Crystal Forcing, Icicle, and Long White Spanish Winter.

After a number of preliminary tests it was found that the most satisfactory method for the germination and the growth of the seedlings for our purpose was as follows. The seeds were soaked in distilled water for about four hours and were then placed in germinators, constructed by placing a granite pan into a larger one containing a little water. The smaller pan was covered with a cloth whose free edges dipped into the water of the outer pan. On this cloth, kept constantly moist by capillarity, the soaked seeds were placed and the whole covered with a pan to prevent drying. These germinators were kept in a warm room. After two days a definite number of seedlings showing equal growth were transfered to perforated paraffine blocks described below, and floated on the water or nutrient solutions. Measurements in centimeters of the length of the shoot were taken at the end of the third, sixth and twelveth days. After that period it was found that no further growth took place in the etiolated plants, and many began to die.

All of the seedlings were grown in water cultures. The water used in making up the nutrient solutions was redistilled in Jena glass after a first distillation in the laboratory still of heavily tinned copper. The supply was stored in glass vessels. The solutions were made up of Merck's chemically pure salts as

described under the appropriate heads.

The paraffine blocks above mentioned were one quarter of an inch in thickness and three inches in diameter. These blocks were prepared by boiling commercial paraffine in several changes of distilled water to remove any soluble impurities which might be present. The melted paraffine was poured into a dish containing water and allowed to cool. The larger sheets were cut into forms of the desired size. Twenty holes were bored in each block for holding the seedlings in position.

The young plants were grown both in the light and darkness and under temperature conditions as follows. The highest temperature range was from 25° to 30° C.; the intermediate from 20° to 25° C.; and the low from 15° to 20° C.

Solutions of the following composition were used for growing the seedlings. The care required in making them is mentioned later.

I. Tap Water of the University supply, as reported by the Water Survey Bulletin (1):

	Milligrams per 1000 cc.
Potassium	2.6
Sodium	29.0
Ammonium	2.3
Magnesium	34.9
Calcium	70.1
Oxide of Iron & Aluminium	1.0
Silica	18.9
Bases	----

Nitrates	0.7
Chlorine	3.5

II. Distilled Water, which had been redistilled through Jena glass as described.

III. Complete Nutrient Solution. This complete nutrient solution was first used by Tollens (30) and later by Pfeffer (17). In its preparation the method given by Tollens was followed. The different salts were dissolved in definite quantities of water and the solutions then mixed; the iron being added last to guard against the formation of iron phosphate in undue quantity. Pfeffer makes mention of the fact that some of the substances formed are only slightly soluble, but as the quantity of these in solution is absorbed by the plants more dissolves, keeping the supply constant. These nutrient solutions are slightly acid and this helps to keep the substances in solution. The solution was prepared in four liter bottles according to the formula below and thoroughly stirred before poured into the jars furnished with the seedlings.

Calcium nitrate	1.0 gram
Potassium chloride	0.25 "
Potassium phosphate (dibasic)	0.25 "
Magnesium sulfate	0.25 "

A few drops of ferric chloride

In one liter of distilled water.

IV. Nutrient Solution lacking Phosphorous: The potassium phosphate (dibasic) is replaced by potassium nitrate.

Calcium nitrate	1.00 gram
Potassium chloride	0.25 "
Potassium nitrate	0.25 "
Magnesium sulfate	0.25 "

A few drops of ferric chloride

In one liter of distilled water.

V. Nutrient Solution lacking Potassium: The potassium chloride is replaced by sodium chloride, and the potassium phosphate (dibasic) by mono-calcium phosphate.

Calcium nitrate	1.00 grams
Sodium chloride	0.25 "
Magnesium sulfate	0.25 "
Mono-calcium phosphate	0.25 "

A few drops of ferric chloride

In one liter of distilled water

VI. Nutrient Solution lacking Nitrogen: The calcium nitrate is replaced by calcium sulfate.

Calcium sulfate	1.00 gram
Potassium chloride	0.25 "
Potassium phosphate (dibasic)	0.25 "
Magnesium sulfate	0.25 "

A few drops of ferric chloride

In one liter of distilled water.

VII. Nutrient Solution lacking Magnesium. The magnesium sulfate is replaced by calcium sulfate.

Calcium nitrate	1.00 gram

Potassium chloride	0.25 gram
Potassium phosphate	0.25 "
Calcium sulfate	0.25 "
A few drops of ferric chloride	
In one liter of distilled water.	

VIII. Nutrient Solution lacking Potassium: Potassium chloride is omitted thus changing the concentration as well as the chemical composition; the potassium phosphate (dibasic) is replaced by mono-calcium phosphate.

Calcium nitrate	1.00 gram
Magnesium sulfate	0.25 "
Mono-calcium phosphate	0.25 "
A few drops of ferric chloride	
In one liter of distilled water.	

IX. Nutrient Solution lacking Phosphorous: The potassium phosphate (dibasic) is omitted thus changing the concentration as well as the chemical composition.

Calcium nitrate	1.00 gram
Potassium chloride	0.25 "
Magnesium sulfate	0.25 "
A few drops of ferric chloride	
In one liter of distilled water.	

X. Distilled water with 0.3 percent. of calcium nitrate and 0.3 percent. of magnesium sulfate.

XI. Distilled water with 0.3 percent. of calcium nitrate.

XII. Distilled water with 0.2 percent. of magnesium sulfate.

Discussion.

Seedlings Grown in Tap Water.

Seedlings grown in tap water of the above composition make a greater growth than those grown in distilled water. In neither of these however is the growth as great as in some of the solutions discussed later.

A study of Tables 1, 13, 25, 37 and Plates 1 to 10 shows that the different varieties with the single exception of the Long White Spanish Winter, both in the light and in the dark, make about the same growth at the respective temperatures. The growth of seedlings of the different varieties with the exception of the one noted, is greatest in the etiolated plants at low temperatures, and in the green plants at the intermediate temperatures. The Long White Spanish Winter variety at the intermediate temperatures shows both in the green and etiolated seedlings a markedly decreased growth.

Seedlings Grown in Distilled Water.

An examination of Tables 2, 14, 26, 38 and Plates 1 to 10 shows that seedlings in distilled water soon cease growth and die. This is in accordance with the conclusions noted by Dr. Godlewski (3, 4), Schreiner, Oswald and Skinner (19), Livingston (8), Loew (9), and Schoutz (18). The poor growth may be due to the absence of the mineral constituents necessary for the growth of the seedling as Godlewski concluded, or may be due to the toxicity of distilled water (rendered non-toxic by the addition of mineral

salts as Livingston maintains.). The latter author beleives that the toxicity is more especially corrected by calcium salts. The copper carried over in the process of distillation is usually held responsible for the toxicity of distilled water. In preliminary trials not recorded in this paper I found that by adding carbon black to the distilled water from the laboratory still an increase in growth was not apparent and this was not changed by redistillation through Jena glass.

The results here show that the poor growth in distilled water is not due to toxicity. Further the unequal growth of the different varieties at different temperatures in distilled water shows that the poor growth is not the result of poison. The seedlings grown at high temperatures show only a slightly poorer growth than those at low temperatures, which is contrary to expectation were the poor growth due to the presence of toxic agents. In the distilled water as in the tap water the seedlings show a marked uniformity in the growth of the different varieties both in the dark and in the light.

From the results here recorded it becomes apparent that the redistilled water does not have a toxic effect, and that the poor growth must be due to the lack of mineral nutrients - and this becomes further apparent in the following.

Seedlings Grown in Complete Nutrient Solution.

Since the seedlings of the radish failed to develop in distilled water and this failure being evidently not due to the toxic effect of the distilled water, naturally the next step is to

determine what mineral elements are essential for a proper growth. Duggar (2) states that it is probable there is no one ideal nutrient solution since plants vary so widely in their requirements. The problem then is to determine one for the radish seedlings in question. The method of finding the mineral requirements of the radish seedlings is one of trial and error. It then seems best to take a recognized nutrient solution for a trial and make modifications of the quantity of the ingrediants as well as the ingrediants themselves. Proceeding along this line the nutrient solution already given was choosen.

The data of Tables 3, 15, 27, 39 and Plates 1 to 10 show that the best growth of the seedlings does not take place in the so-called normal nutrient solution of the above composition.

The different varieties do not differ much in their growth in this solution. The maximum growth of all the varieties both in the light and in the dark and at the different temperatures is made by the Long White Spanish Winter and Dreer's Crystal Forcing.

From the results we may conclude that the complete nutrient solution as used by Tollens is not a balanced one for the radish seedlings in question. I proceeded then to vary the solution acting upon the suggestions obtained from Osterhaut (14) in a paper on "The Importance of Physiologically Balanced Solutions for Plants"; and Loew (10) in a publication discussing the importance of the different elements and their influence on the growth of different seedlings.

Seedlings Grown in Nutrient Solution lacking Phosphorous.

The first variation which I tried was the elemination of phosphorous from the solution and replacing it with potassium nitrate. The relation and importance of phosphorous in the growth of the seedlings is suggested by Schreiner, Oswald, and Skinner (19). They found that of the nutrient elements phosphorous was of the least importance in the early growth of the seedlings experimented on, and that it might be eliminated without marked effect. Potassium on the other hand was largely used by the seedling and was necessary for proper growth.

Tables 4, 16, 28, 40 and Plates 1 to 10 show the results that I obtained with the radish seedlings are similar to those obtained by the above authors. Dreer's Crystal Forcing variety makes a growth equal to or better than that made by seedlings grown in the complete nutrient solution, at all temperatures except the intermediate temperatures in the light. The Round Red Forcing variety makes a better growth of the etiolated plants in the high temperatures, and in the green plants in the intermediate temperatures, than in the complete nutrient solution. The Icicle variety makes a greater growth of the etiolated plants at the intermediate temperatures and equal to the complete nutrient solution at the high temperatures. The Long White Spanish Winter makes a greater growth at the high temperatures of the etiolated seedlings, and at the intermediate temperatures of the green seedlings.

It is observed that all the etiolated and green seedlings of Dreer's Crystal Forcing and Icicle make a better growth at the

low temperatures than at the high or intermediate temperatures.

The data shows that all of the varieties at the high temperatures do as well or better in a solution lacking phosphorous as in a complete nutrient solution; while at low temperatures those lacking phosphorous do not do as well as in the complete nutrient solution.

Seedlings Grown in Nutrient Solution lacking Potassium.

Schreiner, Oswald, and Skinner (19) refered to above found that potassium is essential in the growth of the young seedling and that large amounts of potassium are used by it. Weevers (23) gives the hypothesis that potassium is specially connected with the formation of protoplasm in growing points.

In order to maintain the solution at uniform concentration sodium was substituted for potassium. Experiments upon the substitution of sodium for potassium have been performed by Hartwell and Wheeler (5) and by Hartwell and Pember (6), with the results that when there is a complete lack of potassium, sodium is of some benefit in the growth..

The data of Tables 5, 17, 29, 41 and Plates 1 to 10 show that all of the seedlings grown in the above solution make a poor growth - in no case as good as that of a complete nutrient solution, or of a nutrient solution lacking phosphorous. All varieties show an equally poor growth in nutrient solutions lacking potassium either in the light or in the dark.

Seedlings grown at low temperatures both in the light and in the dark, show a rather marked increase in growth over those grown

at high temperatures.

Seedlings Grown in Nutrient Solution lacking Nitrogen.

The work of Schreiner, Oswald and Skinner (19) can again be referred to here. They found that nitrogen was essential to the growing seedling.

Tables 6, 18, 30, 42 and Plates 1, 3, 5, 6, 7, 8 and 9 show that the seedlings - with the exception of Dreer's Crystal Forcing in the light, and at intermediate temperatures - do not make as good a growth in this solution as in the complete nutrient solution or the nutrient solution lacking phosphorous. However it will be noted that the seedlings - with the exception of the Round Red Forcing at the low temperatures - in this solution make a markedly better growth than in the nutrient solution lacking potassium.

Those grown at low temperatures - excepting the Round Red Forcing variety - made a better growth than at the high temperatures.

The results would tend to show that nitrogen is very essential for the development of the seedling but is not as important as is potassium.

Seedlings Grown in Nutrient Solution lacking Magnesium.

The toxic effect of magnesium salts has received considerable attention. I found the literature upon the importance of magnesium in the growth of plants rather limited. Loew (10) says that the quantity of magnesium needed by the seedling varies, oily seeds requiring more.

A study of Tables 7, 19, 31, 43 and Plates 1 to 10 shows that the seedlings at all of the temperatures make a better growth in the solution lacking magnesium than in the solution lacking nitrogen, with the exception of the Icicle and Long White Spanish Winter at the low temperatures, and the Long White Spanish Winter at the high temperatures in the etiolated plants, and Dreer's Crystal Forcing at the intermediate temperatures in the light. The seedlings also make a better growth in this culture than in that lacking potassium except at the low temperatures. However the growth is not as good as in the complete nutrient solution or the nutrient solution lacking phosphorous.

Dreer's Crystal Forcing shows a marked increased growth over the other varieties in this solution except at the intermediate temperatures in the etiolated seedlings. The growth of the other varieties is about the same.

The results here show that magnesium is needed for the best growth of the radish seedlings, however its importance is not as great as potassium or nitrogen.

Seedlings Grown in Nutrient Solution Lacking Potassium Nitrate.

In order to test the concentration as well as the importance of the minerals themselves I withheld the potassium nitrate, not adding any salt to bring the concentration to that of the normal solution. Schreiner, Oswald and Skinner (19) in their work conclude that the concentration is of less significance than the mineral nutrients. True and Bartlett (21) have made studies upon the concentration of dilute solutions of sodium and magnesium

nitrates upon the pea root and conclude that slight variations in the concentration of the solutions has a marked effect upon the absorption and excretion of the root.

A study of Tables 8, 20, 32, 44 and Plates 1 to 10 shows that the seedlings with the exception of Dreer's Crystal Forcing make no better growth in the solution lacking potassium nitrate, and below the normal concentration, than in a solution the concentration of which was brought to normal by the addition of sodium chloride. The growth is poorer here, with the one exception noted than in most of the other nutrient solutions. This shows that a slight difference in concentration does not have as marked effect upon the growth of the seedlings, as have the mineral constituents. This is in accordance with the experiments of Schreiner, Oswald, and Skinner above mentioned.

Seedlings Grown in Nutrient Solution lacking Potassium Phosphate (dibasic)

In order to further test the slight difference in concentration and the lack of phosphorous as compared with potassium I grew the seedlings in the above solution.

A study of Tables 9, 21, 33, 45 and Plates 1 to 10 shows that the seedlings, with the exception of the Round Red Forcing in the light at the intermediate temperatures, make a better growth in this solution than in any of the other cultures.

The results show that phosphorous in the culture solution is not very essential, if at all, to the growth of the seedlings, and that a solution slightly less concentrated than the complete

nutrient solution above given may be best to secure the best growth of the seedlings.

Solutions of Calcium and Magnesium Salts.

In addition to a study of a complete nutrient solution for these radish seedlings I made a few experiments to study the effect of calcium and magnesium salts upon the seedlings. There has been a large amount of work done on different plants in regard to the relation of magnesium and calcium and their toxicity. Loew (11) has worked upon the physiological function of calcium. Lipman (7), May (13) and Warthiadi (22) upon the function of these salts and the best ratio between them to secure the best growth.

A study of Tables 10, 11, 12, 22, 23, 24, 34, 35, 36, 46, 47, 48 and Plates 1 to 10 shows that the seedlings grown in distilled water to which was added 0.2 % of magnesium sulfate made practically no growth and died within a few days at all temperatures. This shows conclusively the extreme toxicity of magnesium salts alone.

In the solutions of 0.3 % calcium nitrate and 0.3 % magnesium sulfate the seedlings made a fair growth though not as good as in most of the nutrient solutions already discussed. With the exception of Dreer's Crystal Forcing at the intermediate temperatures and Icicle at the high temperatures in the dark, and Dreer's Crystal Forcing and Round Red Forcing in the light, the growth is the same in the calcium nitrate solution or poorer than when both calcium and magnesium salts are used.

The results show that the magnesium is not of very great importance in the growth of the radish seedling and that the extreme toxicity of magnesium is counteracted by the presence of calcium.

Seedlings Grown in Complete Nutrient Solution with varying amounts of Potassium Nitrate.

The foregoing experiments (Tables 5 and 8 and Plates 1 to 10) clearly show that of the mineral salts, potassium is of the greatest importance in the growth of the radish seedlings. Hartwell and Wheeler (5) and Hartwell and Pember (6) carried out extensive experiments on the effect of different quantities of potassium and substitutions for potassium upon wheat and radish seedlings. They found that with deficient amounts of potassium their seedlings made a poorer growth than with maximum amounts, but this poor growth might be slightly increased by the addition of sodium. They make no mention of the variety of radish used and their cheif aim was to find a partial substitute for potassium. A series of experiments were planned with the view of determining the optimum amount of potassium for the varieties of radish used.

A nutrient solution of the composition as given under Solution VIII was prepared and to it were added in series increasing amounts of potassium nitrate as follows: XIII. 0.78 gram

(0.0975 %); XIV. 1.56 grams (0.195 %); XV. 3.12 grams (0.39%); XVI. 4.68 grams (0.585 %); XVII. 6.24 grams (0.78 %); XVIII. 7.80 grams (0.975 %); XIX. 9.36 grams (1.17 %); XX. 15.6 grams (1.95 %); XXI. 28.08 grams (3.51 %). The seedlings were grown in these solutions in the manner already described.

The behavior of the different varieties in solutions of varying concentration of potassium nitrate grown at different temperatures is of marked interest. A study of the data of Tables 49 to 60 and Plates 10 to 16 shows the average growth of the seedlings in these solutions.

At low temperatures (15° - 20° C.) Dreer's Crystal Forcing made a good growth in the nutrient solution lacking potassium, while the other two varieties made a very poor growth in this above solution. In the solution which contained 0.0975 % of potassium nitrate there was a marked increase in growth, Dreer's Crystal Forcing and Icicle reaching their maximum. In the first mentioned variety this was maintained until a concentration of 0.975 % of potassium nitrate was reached. At this concentration growth was markedly checked dropping below that of the solution lacking potassium. Another very marked falling off in the rate of growth occurs at the highest concentration, namely, 3.51 % (Plate 10).

The Icicle variety, aside from the differences already noted, shows a sudden drop in the growth rate at a concentration of 0.195 % solution of potassium nitrate (Plate 10), and a marked increase in the rate at 0.39 %. At this latter concentration the Long White Spanish Winter also made its maximum growth, there being a gradual increase through the series reaching its maximum

at this concentration. Beyond this concentration the growth rate gradually decreases in both of these later varieties to the killing point at a concentration of 3.51 % potassium nitrate.

At intermediate temperatures (20° - 25° C.) the growth made was distinctly less than at low temperatures. Dreer's Crystal Forcing again made the best growth in the nutrient solution lacking potassium. The other three varieties made fair growths in this solution. All the varieties excepting the Long White Spanish Winter showed much better growth in the solution to which had been added 0.0975 % of potassium nitrate. Dreer's Crystal Forcing made its greatest growth in this solution and maintained this rate of growth until a concentration of 0.585 % of potassium nitrate was reached, when a decrease in the rate occured and continued until a concentration of 1.17 % of potassium nitrate was reached. At this concentration there occured a second marked increase in the rate of growth. At a concentration of 1.95 % growth was suddenly checked. Growth in all of the varieties ceased at a concentration of 3.51 %. Dreer's Crystal Forcing at intermediate as well as at low temperatures made the best and most uniform growth in the series of solutions.

At high temperatures (25° - 30° C.) the growth of all varieties was poorer than at either the low or intermediate temperatures, Plates 10, 11, 12). Here again the growth curves show two distinct modes one at relatively low concentration of potassium salts and another at a high concentration (Plate 12).

Dreer's Crystal Forcing makes the best growth in the solution lacking potassium of any of the varieties as it did in the other

temperature ranges. At the lowest concentration of potassium nitrate, 0.0975 %, the Long White Spanish Winter and Icicle made a very marked increase in growth, followed by a decreased growth in the solutions of increasing concentrations. The Long White Spanish Winter made a slightly increased growth at a concentration of 0.78 % which decreased in the 0.976 %, and again increased in the solution of 1.17 % concentration. Beyond this concentration growth was greatly checked as at the other temperatures. The Icicle and Long White Spanish Winter showed an increased growth in 0.78 % potassium nitrate, which in the former reached its maximum at a concentration of 0.975 %, while the latter slightly decreased, and again rose rapidly reaching its maximum at 1.17 %. (Plate 12). From this there was a rapid decline to the highest concentration of 3.51 % where there was no growth in the Icicle. All other varieties showed slight growth at this concentration and temperature.

The Round Red Forcing in the solution minus potassium made the poorest growth of any of the varieties used. In a solution containing 0.0975 % potassium nitrate there was a marked increase in growth, in fact this variety here reaching its maximum. From this concentration growth markedly decreased to a concentration of 0.39 %, and then a gradually increasing growth at the succeeding concentrations until 1.17 % was reached. The Long White Spanish Winter also at this concentration showed a marked increase. A decrease in growth was shown at the two higher concentrations, as in the other varieties.

Dreer's Crystal Forcing made a much poorer growth at the high

temperatures than at either the intermediate or low temperatures. The growth there being no better than the other varieties. At the 0.0975 % and 0.195 % concentrations it made a poorer growth than in the nutrient solution lacking potassium. This is in marked contrast to its growth at the other temperatures, or of the other varieties at any temperature. There was a marked increase at a concentration of 0.39 % and this was maintained to 0.585 %. A decreased growth occured at 0.78 % and another increase at a 0.975 % concentration and this was maintained in the 1.17 %. Growth as in the other varieties was checked at the two highest concentrations.

A study of Plates 13, 14, 15, and 16 shows that the seedlings in most cases make the best growth at low temperatures (15°- 20° C.) and poorest growth at high temperatures (25°- 30° C.)

The results of these experiments show that potassium is very essential in the growth of the radish seedlings. That the different varieties do not have the same optimum requirements of potassium salts. That the temperature is an important factor in the relation of potassium salts. That at the higher temperatures the curve for growth (Plates 11, 12) show two optima at quite widely different concentrations.

Conclusions

The results of the investigations reported in this thesis warrant the following conclusions:-

The radish seedlings studied make a poor growth in distilled water not because of its toxic effect, but because of the lack of nutrient salts.

The nutrient salts of a normal nutrient solution are not all essential to the growth of the radish seedling.

A socalled complete nutrient solution is not a balanced one for the radish seedlings in question.

Potassium and nitrogen are very essential in the growth of the radish seedlings.

Phosphorous and magnesium are not very essential in the growth of the seedling, and, under certain conditions a better growth will result when phosphorous is omitted.

Magnesium is exceedingly toxic in minute quantities, but its toxicity is counteracted by calcium.

Slight variations in the concentration of the nutrient solution does not appear to have any marked effect on the growth of the radish seedlings.

Potassium nitrate at relatively low and relatively high concentrations in nutrient solution causes increased growth in the seedlings.

The radish seedlings studied make a better growth at low temperatures (15° - 20° C.) than at high temperatures (25° - 30° C.) in most of the culture solutions.

There is a marked difference in growth between the different varieties in the different nutrient cultures.

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Table 1

Round Red Forcing Radish - grown in Solution I. (Tap Water).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	5	8	8
" 2	7	12	12
" 3	3	6	6
" 4	4	5	6
" 5	4.5	10	12
Average			9

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
10	16	16	6	13	15
3	4	5	5	6	6
		11			10

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
7	9	12	3	5	8
4	12	12	2	6	6
		12			7

Table 2

Round Red Forcing Radishes - grown in Solution II (distilled water)

Temperature 25° - 30° C.

Etiolated Plants

Growth in;)	3 da.	6 da.	12 da.
Trial 1	3	7	7
" 2	3	5	5
" 3	3	4	4
" 4	3	6	7
Average			6

Temperature 20° - 25° C.

Growth in:-	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.		3 da.	6 da.	12 da.
6	8	8		3	4	4
3	4	4		1.5	2	2
2	3	3		1	2	2
		5		2	2	2
						2.5

Temperature 15° - 20° C.

Growth in:-	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.		3 da.	6 da.	12 da.
6	9	9		3	5	7
3	4	6		1.5	3	7
2	5	11		2	3	3
2	8	8	8.6	2	5	5 5.4

Table 3

Round Red Forcing Radishes - grown in Solution III (Complete Nutrient Solution)

Temperature 25° - 30° C.

Etiolated Plants

Growth in:-	3 da.	6 da.	12 da.
Trial 1	6	9	10
" 2	4	6	7
" 3	6	14	16
Average			11

Tempaerature 20° - 25° C.

Growth in:-	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
6	11	11	4	5	6
			4	6	7
		11			6.5

Temperature 15° - 20° C.

Growth in:-	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
8	9	10	4	8	8
7	12	13	4	10	10
12	15	15	3	6	7
7	15	16			
		13.5			8.3

Table 4

Round Red Forcing Radishes - grown in Solution IV. (Nutrient Solution lacking Phosphorous)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	9	12	14
" 2	8	11	14
" 3	3	6	6
Average			11.3

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
8	9	9	5	8	10
			5	7	10
		9			10

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
4	7	9	3	7	9
4	13	14	4	6	7
8	12	13	3	6	10
5	14	15			
		13			8.6

Table 5

Round Red Forcing Radishes - grown in Solution V. (Nutrient Solution lacking Potassium)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	7	8
" 2	4	4	5
" 3	2	5	7
Average			6.6

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.	
7	10	10	3	4	4	
			3	5	7	
		10			5.5	

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.	
5	9	10	3	8	8	
4	15	15	3	5	5	
4	8	9	2	7	9	
4	10	12				
		11.5			7.3	

Table 6

Round Red Forcing Radish - grown in Solution VI. (Nutrient Solution lacking Nitrogen)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	6	9	11
" 2	6	7	7
Average			9

Temperature 20° - 25° C.

Green Plants

Growth in cm. in:	3 da.	6 da.	12. da.
Trial 1	4	6	8
Average			8

Temperature 15° - 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	7	7
Average			7

Table 7

Round Red Forcing Radish - grown in Solution VII. (Nutrient Solution lacking Magnesium)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	8	9	9
" 2	10	14	14
Average			11.5

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
9	13	13	5	8	9
			4	6	7
		13			8

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
6	9	10	4	7	8
6	7	12	5	8	10
8	10	10			
		11			9

Table 8

Round Red Forcing Radish - grown in Solution VIII. (Nutrient Solution lacking Potassium Chloride)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	2	6	8
Average			8

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	4	8	12	2	10	10
			12			10

Table 9

Round Red Forcing Radish - grown in Solution IX. (Nutrient Solution lacking Potassium phosphate (dibasic)).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	6	14	16
Average			16

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	7	15	18	3	6	8
			18			8

Table 10

Round Red Forcing Radish - grown in Solution X. (Nutrient Solution of 0.3 % calcium nitrate and 0.3 % magnesium sulfate)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	2	4	5
Average			5

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	6	8	10	3	5	5
			10			5

Temperature 15° - 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	5	9	12
Average			12

Table 11

Round Red Forcing Radish - grown in Solution XI. (Nutrient Solution of 0.3 % calcium nitrate)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	2	3	5
Average			5

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	4	8	8	2	3	5
	3	7	9	5	8	8
			8.5			6.5

Temperature 15° - 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	5	9	12
Average			12

Table 12

Round Red Forcing Radish - grown in Solution XII. (Solution of 0.2 % magnesium sulfate)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	1	dead	

Temperature 20° - 25° C.

No growth

Temperature 15° - 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	2	2	dead

Table 13

Dreer's Crystal Forcing Radies - grown in Solution I. (Tap Water)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	5	6
" 2	7	12	12
" 3	7	10	10
" 4	6	10	13
" 5	4.5	10	12
Average			10.5

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
6	9	9	8	12	14
			4	5	5
		9			9

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
10	10	12	7	8	8
6	12	12	3	6	8
		12			8

Table 14

Dreer's Crystal Forcing Radish - grown in Solution II. (Distilled Water)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	7	7
" 2	4	8	8
" 3	3	4	4
" 4	4	12	12
Average			8

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
5	6	6	6	8	8
5	6	7	2	3	3
			2	3	3
		6.5			4.5

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
5	6	10	4	5	5
3	6	7	1	5	7
3	5	9	2	4	5
4	8	9	3	6	7
5	7	10			
		9			6

Table 15

Dreer's Crystal Forcing Radish - grown in Solution III. (Complete Nutrient Solution).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	9	11	12
" 2	6	12	14
" 3	6	18	18
Average			14.5

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
6	12	13	7	10	11
			4	6	8
		13			9.5

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
8	11	13	5	11	12
4	13	14	5	12	13
9	15	18			
		15			12.5

Table 16

Dreer's Crystal Forcing Radish - grown in Solution IV. (Nutrient Solution lacking Phosphorous).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	10	14	16
" 2	5	6	16
" 3	4	9	12
Average			14.5

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
14	15	15	6	9	10
			5	8	10
		15			10

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
10	12	15	3	9	10
5	15	17	8	11	12
12	15	16	4	10	11
8	15	18			
		16.5			11

Table 17

Dreer's Crystal Forcing Radish - grown in Solution V.
(Nutrient Solution lacking Potassium).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	9	10
" 2	4	7	7
" 3	2	5	7
Average			8

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
8	13	13	6	10	11
			1	3	4
		13			7.5

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
7	9	10	2	5	6
3	10	12	4	4	6
7	9	9	3	8	8
6	14	14			
		11			7

Table 18

Dreer's Crystal Forcing Radish - grown in Solution VI. (Nutrient Solution lacking Nitrogen).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	10	10	12
" 2	8	9	11
Average			11.5

Temperature 20° - 25° C.

Green Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	6	10	11
Average			11

Temperature 15° - 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	7	11	13
Average			13

Table 19

Dreer's Crystal Forcing Radishes - grown in Solution VII . (Nutrient Solution lacking Magnesium).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	9	12	14
" 2	9	10	15
Average			14.5

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
8	11	12	6	8	10
			3	6	8
		12			9

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
10	12	15	5	12	13
6	15	16	4	10	11
10	12	12			
		14.5			12

Table 20

Dreer's Crystal Forcing Radish - grown in Solution VIII.
(Nutrient Solution lacking Potassium Chloride)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	10	14
Average			14

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
	3da.	6 da.	12 da.	3 da.	6 da.	12 da.
	6	12	14	4	8	8
			14			10

Table 21

Dreer's Crystal Forcing Radish - grown in Solution IX.
(Nutrient Solution lacking Potassium Phosphate (dibasic)).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	7	18	18
Average			18

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	8	16	18	5	12	13
			18			13

Table 22

Dreer's Crystal Forcing Radish - grown in Solution X. (Nutrient Solution of 0.3 % Calcium nitrate and 0.3 % magnesium sulfate).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3da.	6 da.	12 da.
Trial 1	5	6	6
" 2	5	8	10
Average			8

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
5	7	8	4	5	5
		8			5

Temperature 15° - 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	10	11	12
Average			12

Table 23

Dreer's Crystal Forcing Radish - grown in Solution XI.

(Nutrient Solution of 0.3 % calcium nitrate)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	5	5	5
" 2	4	7	10
Average			7.5

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	12	15	15	6	10	12
	4	7	7	4	6	6
			11			9

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	8	10	12	8	9	12
			12			12

Table 24

Dreer's Crystal Forcing Radish - grown in Solution XII.
(Solution of 0.2 % magnesium sulfate).

Temperature 25°- 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	2	dead	

Temperature 20°- 25° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	1	dead		2	dead	

Temperature 15°- 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	6	6	7

Table 25

Icicle Radish - grown in Solution I. (Tap Water).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	8	9
" 2	4	12	14
" 3	2	4	4
" 4	4	7	8
" 5	2	9	12
Average			9

Temperature 20° - 25° C.

Growth in::	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
8	15	15	3	8	10
4	6	6	4	6	6
		10.5			8

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
7	10	12	3	6	7
3	5	10			
		11		7	7

Table 26

Icicle Radish - grown in Solution II. (Distilled Water).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	8	10
" 2	2	3	3
" 3	4	5	6
" 4	2	6	10
			7

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
7	12	12	3	3	3
4	5	5	2	2	dead
3	4	4	1	1	1
			1	1	1
		7			1.5

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
7	8	10	1	2	5
1	2	4	2	3	5
2	7	8	2	5	6
4	7	9			
4	8	10			
		8			5

Table 27

Icicle Radish - grown in Solution III. (Complete Nutrient Solution).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	8	10
" 2	4	6	7
" 3	5	10	15
Average			10.7

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
4	10	10	4	6	10
			2	4	8
		10			9

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
5	10	12	2	9	13
1	14	14	8	10	10
12	13	14			
7	14	15			
		13.5			11.5

Table 28

Icicle Radish - grown in Solution Iv. (Nutrient Solution lacking Phosphorous).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	8	9	10
" 2	4	10	10
" 3	3	8	12
			10.7

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
3	11	11	3	6	8
			2	6	6
		11			7

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
4	5	10	3	8	10
6	12	16	5	8	9
6	8	11			
7	15	16			
		13			9.5

Table 29

Icicle Radish - grown in Solution V. (Nutrient Solution lacking Potassium).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	5	8	9
" 2	3	6	7
" 3	2	5	7
Average			7.7

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
3	5	5	4	5	6
			1	2	5
		5			5.5

Temperature 15° - 20° C.

Growth in:	Etiolated plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
4	5	8	2	4	10
3	12	15	4	6	8
6	12	13			
4	7	10			
		11.5			9

Table 30

Icicle Radish - grown in Solution VI. (Nutrient Solution lacking Nitrogen)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	7	10	12
" 2	5	6	6
Average			9

Temperature 20° - 25° C.

Green Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	5	7
Average			7

Temperature 15° - 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	5	7	12
Average			12

Table 31

Icicle Radish - grown in Solution VII. (Nutrient Solution lacking Magnesium)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	5	10	12
" 2	6	9	12
Average			12

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.	
4	10	11	4	6	8	
			2	4	5	
		11			6.5	

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.	
5	7	9	1	8	10	
5	11	12	4	4	6	
4	8	8				
		10			8	

Table 32

Icicle Radish - grown in Solution VIII. (Nutrient Solution lacking Potassium chloride)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	2	6	8
Average			8

Temperature 15° - 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	7	11
Average			11

Table 33

Icicle Radish - grown in Solution IX. (Nutrient Solution lacking Potassium Phosphate(dibasic)).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	6	14	16
Average			16

Temperature 15° - 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	8	15	18

Table 34

Icicle Radish - grown in Solution X. (Nutrient Solution of 0.3 % calcium nitrate and 0.3 % magnesium sulfate).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	2	4	5
Average			5

Temperature 20° - 25° C.

All plants dead.

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	8	10	12	4	8	10
			12			10

Table 35

Icicle Radish - grown in Solution XI. (Nutrient Solution of 0.3 % calcium nitrate).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	3	4	6
Average			6

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
12	15	15	2	8	10
7	9	10			
		12.5			10

Temperature 15° - 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	8	12
Average			12

Table 36

Icicle Radish - grown in Solution XII. (Solution of 0.2 % magnesium sulfate.

Plants in both light and dark died by end of sixth day at all temperatures.

Table 37

Long White Spanish Winter Radish - grown in Solution I. (Tap Water).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	8	11	11
" 2	7	12	13
" 3	4	6	8
" 4	9	10	11
Average			11

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	1	3	4	2	2	3
			4			3

Temperature 15° - 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	8	10	12
Average			12

Table 38

Long White Spanish Winter Radish - grown in Solution II.

(Distilled Water)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	2	6	8
" 2	1	2	2
" 3	3	4	4
Average			5

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
5	8	10	1	2	3
2	3	3	1	4	8
1	2	3	1	2	2
		5.3			4.3

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
4	6	10	1	3	5
3	5	8	1	1	4
1	5	8			
2	4	8			
		8.5			4.5

Table 39

Long White Spanish Winter Radish - grown in Solution III. (Complete Nutrient Solution).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	8	9
" 2	11	14	15
Average			12

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	10	14	14	2	9	9
			14			7

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	10	14	16	3	12	15
	6	16	18	5	10	11
	10	15	16			
			16.6			13

Table 40

Long White Spanish Winter Radish - grown in Solution IV.

(Nutrient Solution lacking Phosphorous)

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	10	12	14
Average			14

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	8	11	11	3	7	11
				5	6	7
			11			9

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	6	9	13	2	8	10
	3	14	15	2	6	7
	10	15	16			
			14.3			8.5

Table 41

Long White Spanish Winter Radish - grown in Solution VI. (Nutrient Solution lacking Potassium).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	3	6	10
" 2	4	8	10
Average			10

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
6	10	11	1	3	3
			5	8	9
		11			6

Temperature 15° - 20° C.

Growth in:	Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
4	7	10	4	8	10
4	15	16	2	8	10
2	5	9			
		11.6			10

Table 42

Long White Spanish Winter Radish - grown in Solution VI.

(Nutrient Solution lacking Nitrogen)

Temperature 25° - 30° C.

Etiolated plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	7	12	14
" 2	6	8	10
Average			12

Temperature 20° - 25° C.

Green plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	3	6	7
Average			7

Temperature 15° - 20° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	8	10	15
Average			15

Table 43

Long White Spanish Winter - grown in Solution VII.

(Nutrient Solution lacking Magnesium)

Temperature 25°- 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	7	10	10
" 2	6	12	12
			11

Temperature 20°- 25° C.

Growth in: Etiolated Plants			Green Plants		
3 da.	6 da.	12	3 da.	6 da.	12 da.
6	8	13	1	4	7
			2	4	5
		13			6

Temperature 15°- 20° C.

Growth in: Etiolated Plants			Green Plants		
3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
4	6	10	1	7	10
2	6	7	2	3	3
2	10	14			
		10.3			6.5

Table 44

No data

Table 45

No data

Table 46

Long White Spanish Winter Radish - grown in Solution X. (Nutrient Solution of 0.3 % calcium nitrate and 0.3 % magnesium sulfate).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	3	5	5
Average			5

Temperature 20° - 25° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial 1	4	6	10
Average			10

Table 47

Long White Spanish Winter Radish - grown in Solution XI. (Nutrient Solution of 0.3 % calcium nitrate-).

Temperature 25° - 30° C.

Etiolated Plants

Growth in cm. in:	3 da.	6 da.	12 da.
Trial	2	3	3
Average			3

Temperature 20° - 25° C.

Growth in:	Etiolated Plants			Green Plants		
	3 da.	6 da.	12 da.	3 da.	6 da.	12 da.
	4	6	10	3	6	10
	2	3	7			
			8.5			10

Table 48

Long White Spanish Winter Radish - grown in Solution XII. (Solution of 0.2 % magnesium sulfate).

The plants at all temperatures were killed in this solution within four days and there was no growth over one-half centimeter.

Table 49

Round Red Forcing Radish (Etiolated Plants) - grown in Nutrient Solutions with varying amounts of potassium nitrate.

Temperature 25° - 30° C.

Solution	Trial	3 da.	6 da.	12 da.	Average
VIII	1	2	3	3	3
XIII	1	3	4	6	
	2	2	3	5	5.5
XIV	1	10	12	12	
	2	5	10	11	11.5
XV	1	6	6	6	
	2	5	8	9	7.5
XVI	1	9	10	10	
	2	5	8	9	9.5
XVII	1	9	10	10	
	2	6	8	10	10
XVIII	1	9	10	10	
	2	5	8	10	10
XIX	1	10	10	10	
	2	8	10	12	11
XX	1	12	14	15	
	2	4	5	6	11.5
XXI	1	8	8	8	
	2	0	0	0	4

Table 50

Round Red Forcing Radish (Etiolated Plants) - grown in Nutrient Solution with varying amounts of potassium nitrate.

Temperature 20° - 25° C.

Solution	Trial	Growth in cm. in: 3 da.	6 da.	12 da.	Average
VIII	1	8		10	
	2	8		9	
	3	8		12	
	4	2	4	5	9
XIII	1	8		14	
	2	8		10	
	3	8		10	
	4	3	9	10	11
XIV	1	8		14	
	2	8		12	
	3	8		12	
	4	3	9	12	12.5
XV	1	8		14	
	2	8		12	
	3	8		12	
	4	2	7	10	12
XVI	1	8		9	
	2	8		12	
	3	8		14	
	4	2	8	9	11
XVII	1	8		12	
	2	8		8	
	3	8		14	
	4	2	5	8	10.5
XVIII	1	8		11	
	2	8		8	
	3	8		12	
	4	2	4	7	9.5
XIX	1	8		12	
	2	8		15	
	3	8		12	
	4	1	5	12	12.6

Table 50 continued

Solution	Trial	3 da.	6 da.	12 da.	Average
XX	1	8		12	
	2	8		8	
	3	8		10	
	4	2	3	6	9
XXI	1	8		dead	
	2	8		"	
	3	8		"	0

Table 51

Dreer's Crystal Forcing Radish (Etiolated plants) - grown in Nutrient Solution with varying amounts of potassium nitrate.

Temperature 25° - 30° C.

Solution	Trial	Growth in cm. in: 3 da.	6 da.	12 da.	Average
VIII	1	2	4	4	
	2	5	8	9	6.5
XIII	1	3	5	5	
	2	3	5	6	5.5
XIV	1	5	6	6	
	2	2	5	6	6
XV	1	10	11	12	
	2	3	5	7	10
XVI	1	6	7	7	
	2	8	10	12	10
XVII	1	3	4	5	
	2	8	12	12	8.5
XVIII	1	8	10	10	
	2	7	10	12	11
XIX	1	6	10	10	
	2	4	6	12	11
XX	1	8	10	10	
	2	4	5	7	8.5
XXI	1	0	2	2	
	2	3	4	6	4

Table 52

Dreer's Crystal Forcing Radish (Etiolated Plants) - grown in Nutrient solution with varying amounts of potassium nitrate.

Temperature 20° - 25° C.

Solution	Trial	Growth in cm. in: 3 da.	6 da.	12 da.	Average
VIII	1	8		8	
	2	8		12	
	3	8		15	
	4	8	8	12	12
XIII	1	8		8	
	2	8		10	
	3	8		10	
	4	4	11	16	14
XIV	1	8		14	
	2	8		14	
	3	8		12	
	4	4	11	16	14
XV	1	8		14	
	2	8		12	
	3	8		12	
	4	4	11	18	14
XVI	1	8		9	
	2	8		10	
	3	8		14	
	4	4	12	18	13
XVII	1	8		10	
	2	8		10	
	3	8		14	
	4	3	10	16	12.5
XVIII	1	8		9	
	2	8		12	
	3	8		12	
	4	3	9	14	12
XIX	1	8		10	
	2	8		12	
	3	8		12	
	4	4	11	18	13

Table 52 continued

Solution	Trial	3 da.	6 da.	12 da.	Average
XX	1	8		12	
	2	8		10	
	3	8		10	
	4	2	4	13	11
XXI	1	8		dead	
	2	8		"	
	3	8		"	0

Table 53

Dreer's Crystal Forcing Radish (Etiolated Plants) grown in Nutrient Solution with varying amounts of Potassium nitrate.

Temperature 15° - 20° C.

		Growth in cm. in:			
Solution	Trial	3 da.	6 da.	12 da.	Average
VIII	1	10	12	13	13
XIII	1	10	15	16	16
XIV	1	12	15	16	16
XV	1	12	15	16	16
XVI	1	12	15	16	16
XVII	1	12	15	16	16
XVIII	1	11	14	16	16
XIX	1	8	9	10	10
XX	1	8	9	10	10
XXI	1	2	3	5	5

Table 54

Icicle Radish (Etiolated Plants) - grown in Nutrient Solution with varying amounts of Potassium nitrate.

Temperature 25° - 30° C.

Solution	Trial	Growth in cm. in: 3 da.	6 da.	12 da.	Average
VIII	1	4	5	6	6
XIII	1	6	12	13	13
XIV	1	5	8	8	8
XV	1	5	8	8	8
XVI	1	4	8	8	8
XVII	1	10	11	12	12
XVIII	1	10	13	14	14
XIX	1	10	10	10	10
XX	1	3	4	8	8
XXI	1	0	0	0	0

Table 55

Temperature 20° - 25° C.

Solution	Trial	Growth in cm. in: 3 da.	6 da.	12 da.	Average
VIII	1	2	6	7	7
XIII	1	2	7	8	8
XIV	1	2	7	10	10
XV	1	2	10	15	15
XVI	1	3	9	10	10
XVII	1	1	5	10	10
XVIII	1	2	7	10	10
XIX	1	2	10	14	14
XX	1	1	1	4	4
XIX	1	0			0

Table 56

Temperature 15° - 20° C.

Solution	Trial	Growth in cm. in: 3 da.	6 da.	12 da.	Average
VIII	1	4	6	6	6
XIII	1	10	15	15	15
XIV	1	5	10	12	12
XV	1	6	14	15	15
XVI	1	6	12	13	13
XVII	1	7	12	13	13
XVIII	1	6	10	12	12
XIX	1	8	12	12	12
XX	1	4	6	8	8
XXI	1	1	1	1	1

Table 57

Long White Spanish Winter (Etiolated Plants) - grown in Nutrient Solution with varying amounts of potassium nitrate.

Temperature 25° - 30° C.

Solution	Trial	Growth in cm. in: 3 da.	6 da.	12 da.	Average
VIII	1	4	5	6	6
XIII	1	6	12	12	12
XIV	1	5	10	10	10
XV	1	5	10	10	10
XVI	1	5	8	8	8
XVII	1	10	10	10	10
XVIII	1	8	8	8	8
XIX	1	10	12	12	12
XX	1	8	8	10	10
XVI	1	1	2	4	4

Table 58

Temperature 20° - 25° C.

Solution	Trial	Growth in cm. in: 3 da.	6 da.	12 da.	Average
VIII	1	2	8	10	10
XIII	1	2	4	10	10
XIV	1	2	4	11	11
XV	1	2	5	12	12
XVI	1	2	2	8	8
XVII	1	1	5	10	10
XVIII	1	1	5	10	10
XIX	1	1	2	10	10
XX	1	1	1	6	6
XXI	1	0			0

Table 59

Temperature 15° - 20° C.

Solution	Trial	Growth in cm. in: 3 da.	6 da.	12 da.	Average
VIII	1	2	3	4	4
XIII	1	3	4	5	5
XIV	1	6	8	10	10
XV	1	12	15	17	17
XVI	1	7	10	15	15
XVII	1	11	14	15	15
XVIII	1	10	12	14	14
XIX	1	10	12	12	12
XX	1	2	4	5	5
XXI	1	0			0

Explanation of Plates 1 to 6

The graphs represented in Plates 1 to 6 were prepared for the more ready interpretation of my results. The ordinates represent the growth in centimeters of the stems of the seedlings, and the abscissae the aqueous cultures in which they were grown, the numbers corresponding to those given in the list above. The different varieties of radishes used are represented by colored lines, to wit:- black, Round Red Forcing; red, Dreer's Crystal Forcing; green, Icicle; and purple, Long White Spanish Winter.

Plate 1. Seedlings (etiolated) grown at the low temperatures and in the dark.

Plate 2. Seedlings (etiolated) grown at the intermediate temperatures and in the dark.

Plate 3. Seedlings (etiolated) grown at the high temperatures and in the dark.

Plate 4. Seedlings (green) grown at the low temperatures and in the light.

Plate 5. Seedlings (green) grown at the intermediate temperatures and in the light.

Explanation of Plates 6 to 10

The graphs represented in Plates 6 to 10 were prepared for the more ready interpretation of the influence of temperatures upon the different varieties of the etiolated radish seedlings studied. The ordinates represent the growth in centimeters of the stems of the seedlings, and the abscissae the aqueous cultures in which they were grown, the numbers corresponding to those given in the list above. The different temperature ranges are represented by colored lines, to wit:- green, low temperatures (15 - 20 C.); black, intermediate temperatures (20 - 25 C.); red, high temperatures (25 - 30 C.).

Plate 6. Round Red Forcing Radish.

Plate 7. Dreer's Crystal Forcing Radish.

Plate 8. Icicle Radish.

Plate 9. Long White Spanish Winter Radish.

Explanation of Plates 10 to 13

The graphs represented in Plates 10 to 13 were prepared for the more ready interpretation of my results in studying the relative amounts of potassium required for the best growth of radish seedlings. The ordinates represent the growth in centimeters of the stems of the seedlings, and the abscissae the solutions in which they were grown. The numbers corresponding to the relative concentrations given in the description above. All of the seedlings were grown in the dark. The different varieties of radishes used are represented by colored lines, to wit:- black, Round Red Forcing; red, Dreer's Crystal Forcing; green, Icicle; and purple, Long White Spanish Winter.

Plate 10. Seedlings grown at low temperatures (15 to 20 C.)

Plate 11. Seedlings grown at intermediate temperatures (20 - 25 C.)

Plate 12. Seedlings grown at high temperatures (25 to 30 C.)

Explanation of Plates 13 to 17

The graphs represented in Plates 13 to 17 were prepared for the more ready interpretation of the influence of temperatures upon the different varieties of etiolated radish seedlings grown in solutions of varying amounts of potassium nitrate. The ordinates represent the growth in centimeters of the stem of the seedlings and the abscissae the different concentrations of potassium nitrate in which they were grown, as given in the discussion. The different temperature ranges are represented by colored lines, to wit: green, low temperatures (15 to 20 C.); black, intermediate temperatures (20 - 25 C.); red, high temperatures (25 - 30 C.).

Plate 13. Round Red Forcing Radish.

Plate 14. Dreer's Crystal Forcing Radish

Plate 15. Icicle Radish.

Plate 16. Long White Spanish Winter Radish.

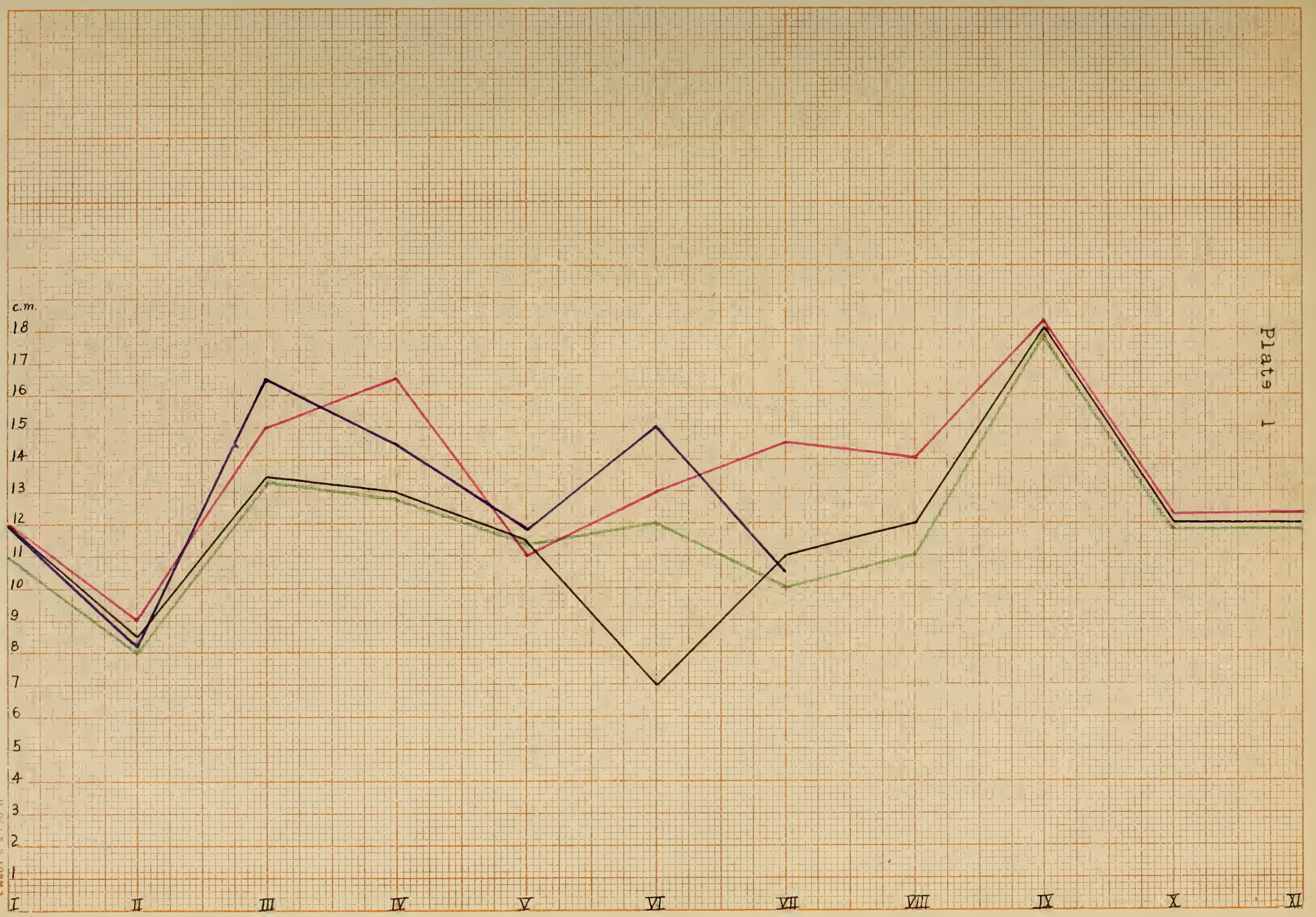
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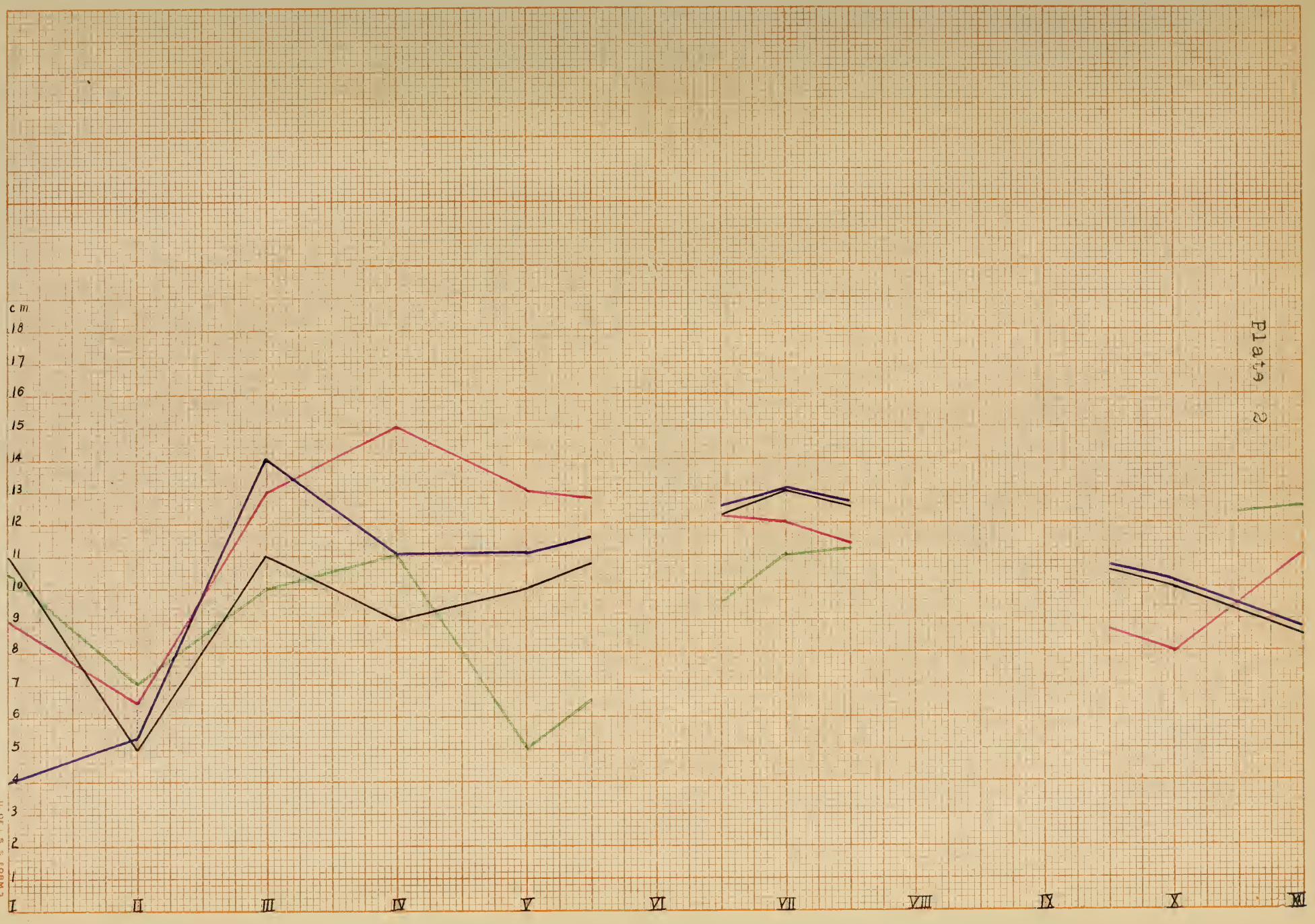
Plate 1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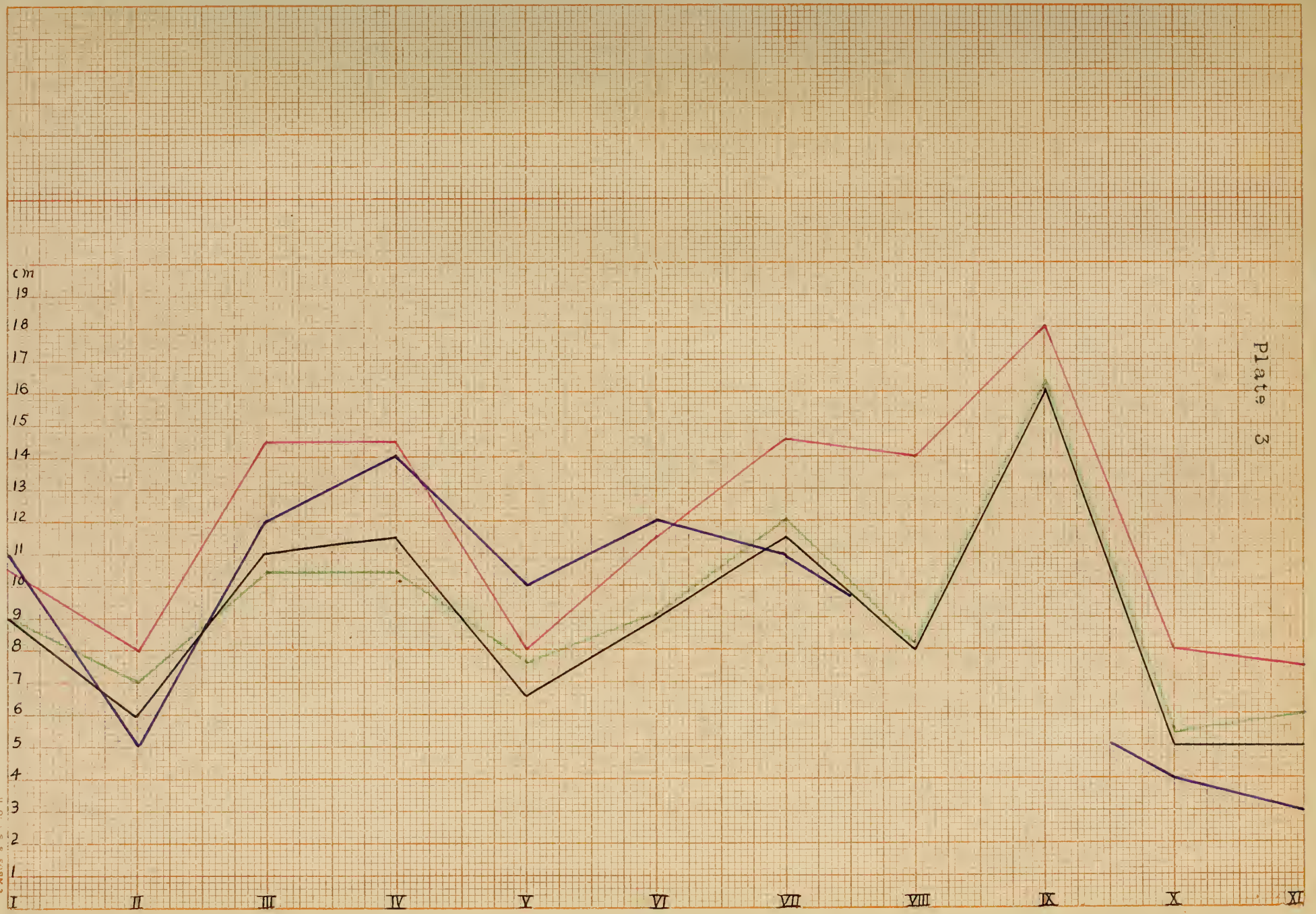
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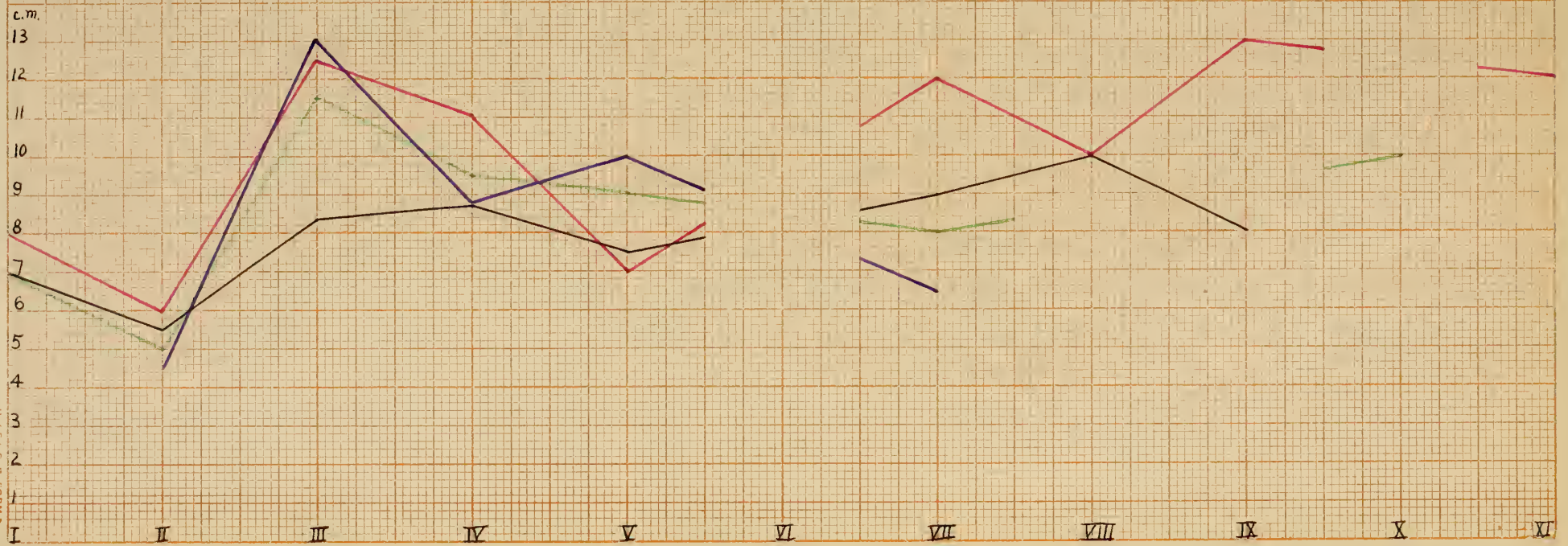
Plate 3

Plate 4



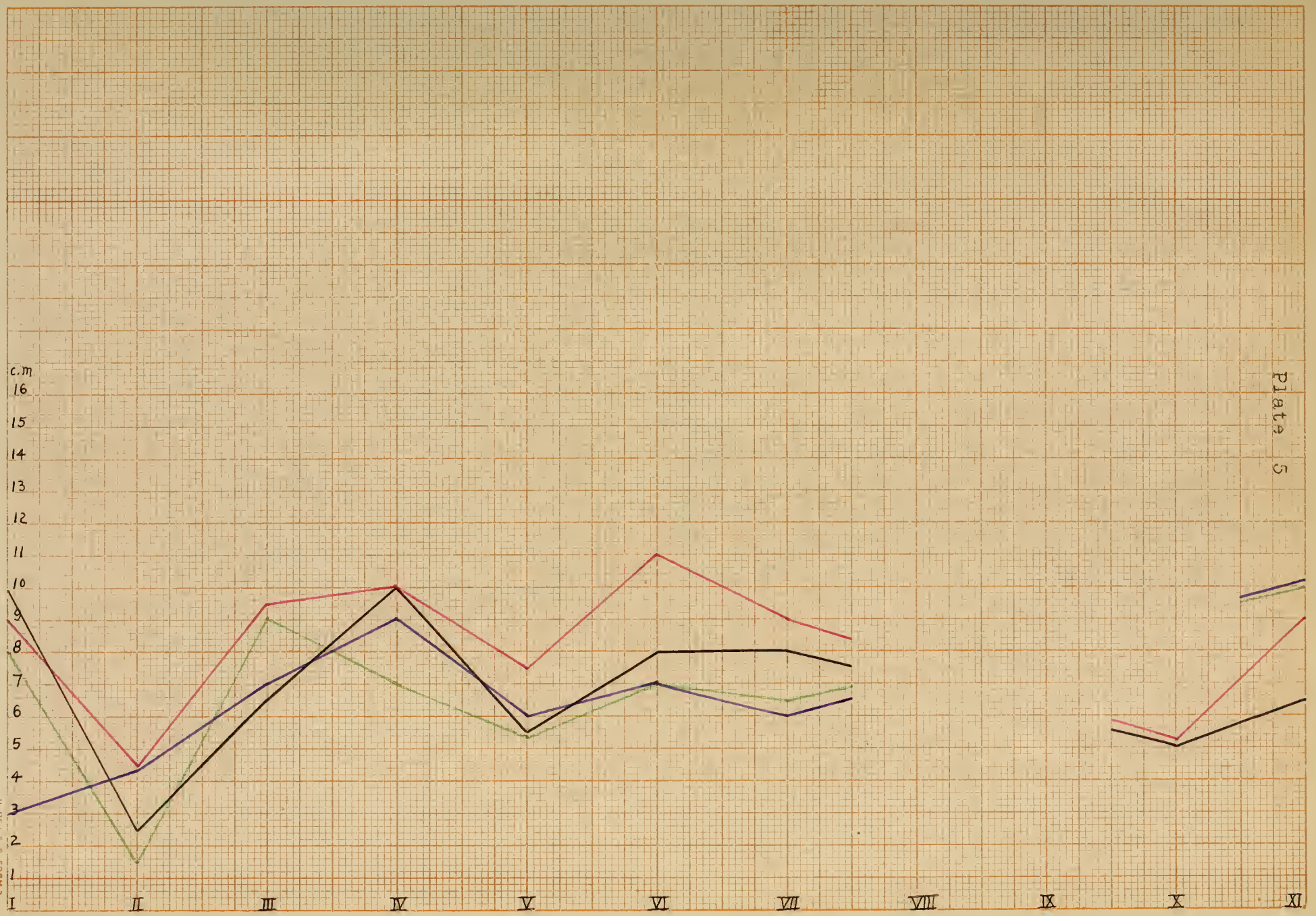


Plate 5

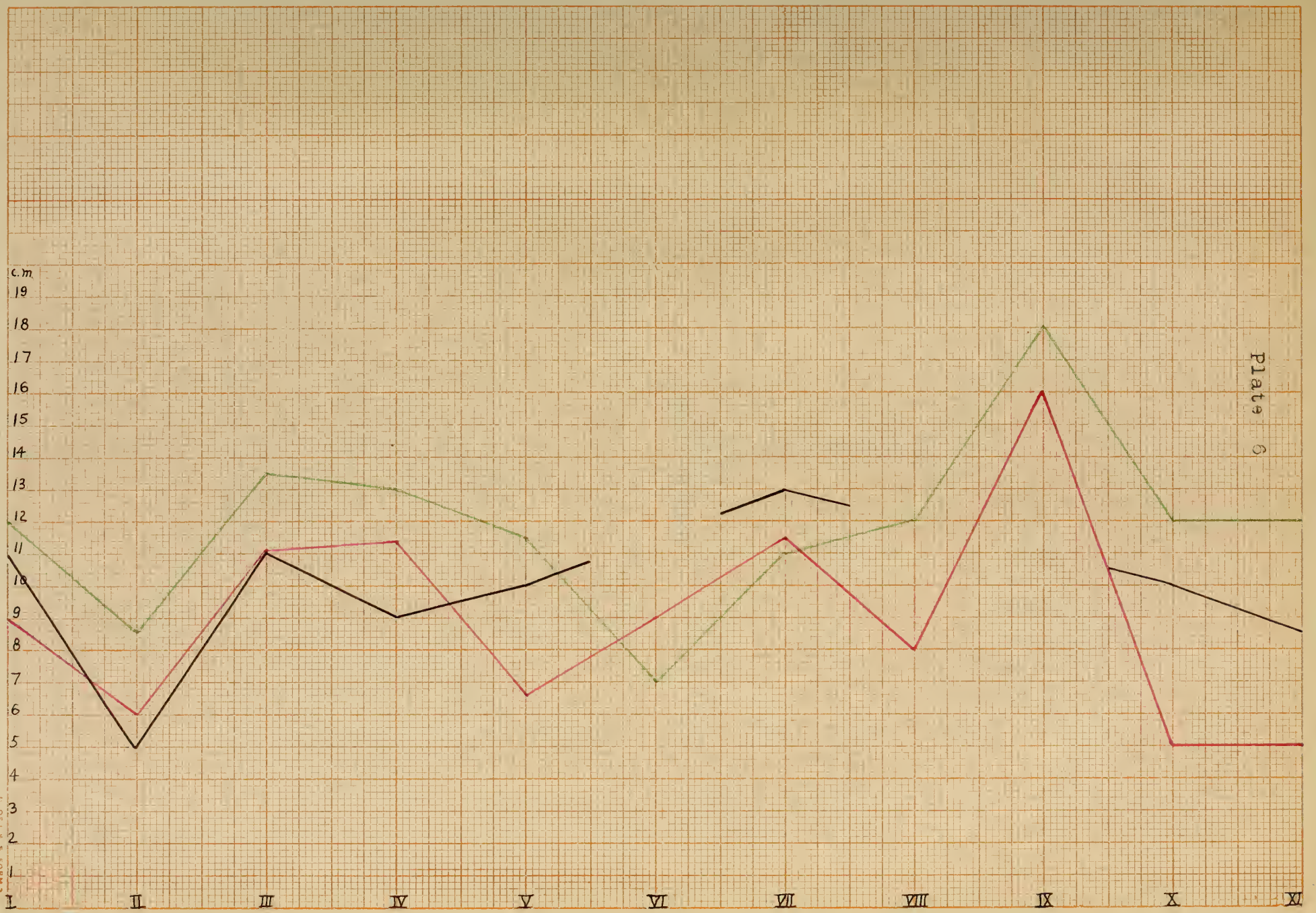

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Plate 6

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Plate 7

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Plate 3

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Plate 9

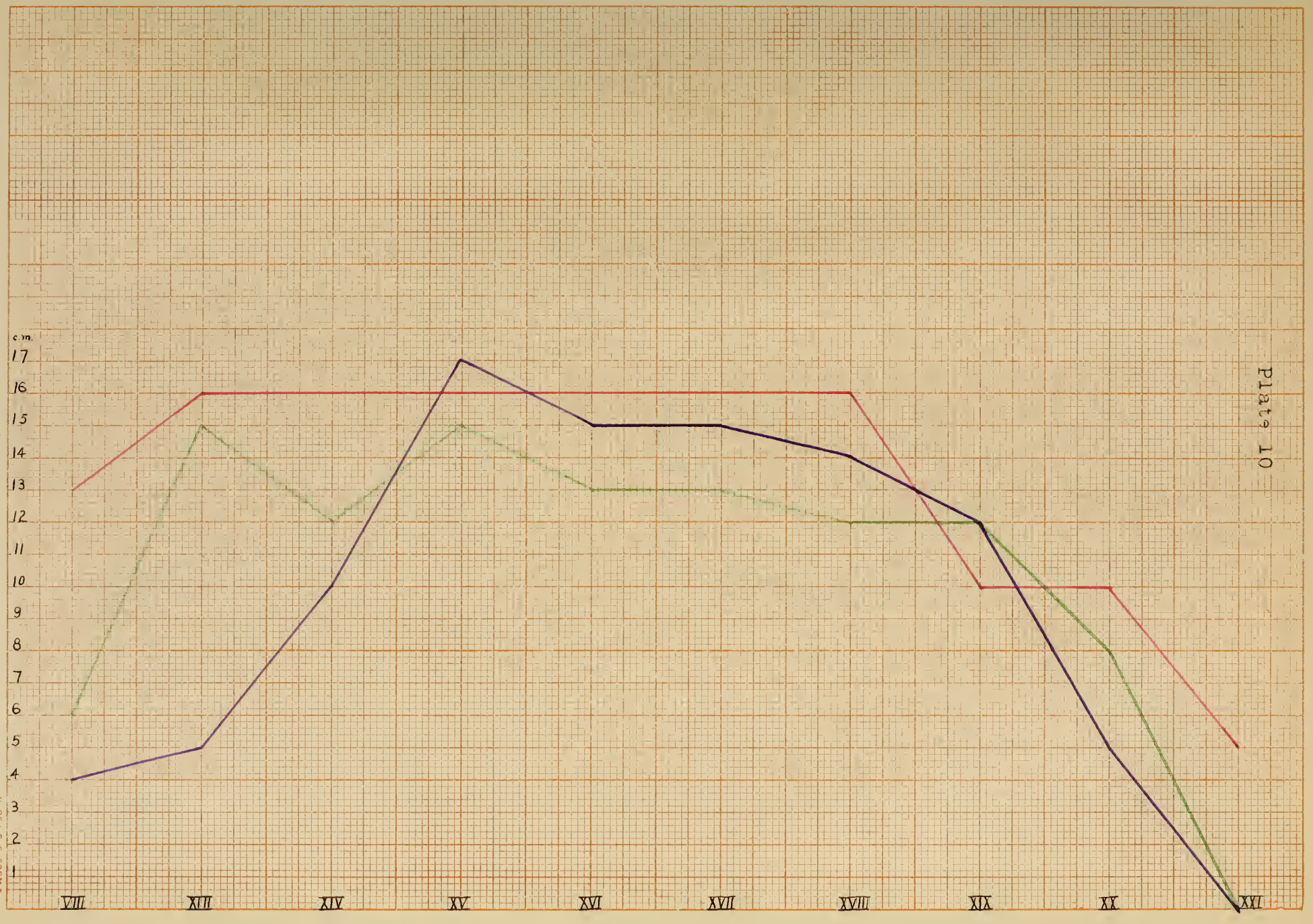

Plate 10

U. OF I. S. S. FORM 3

Plate 11
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XXI

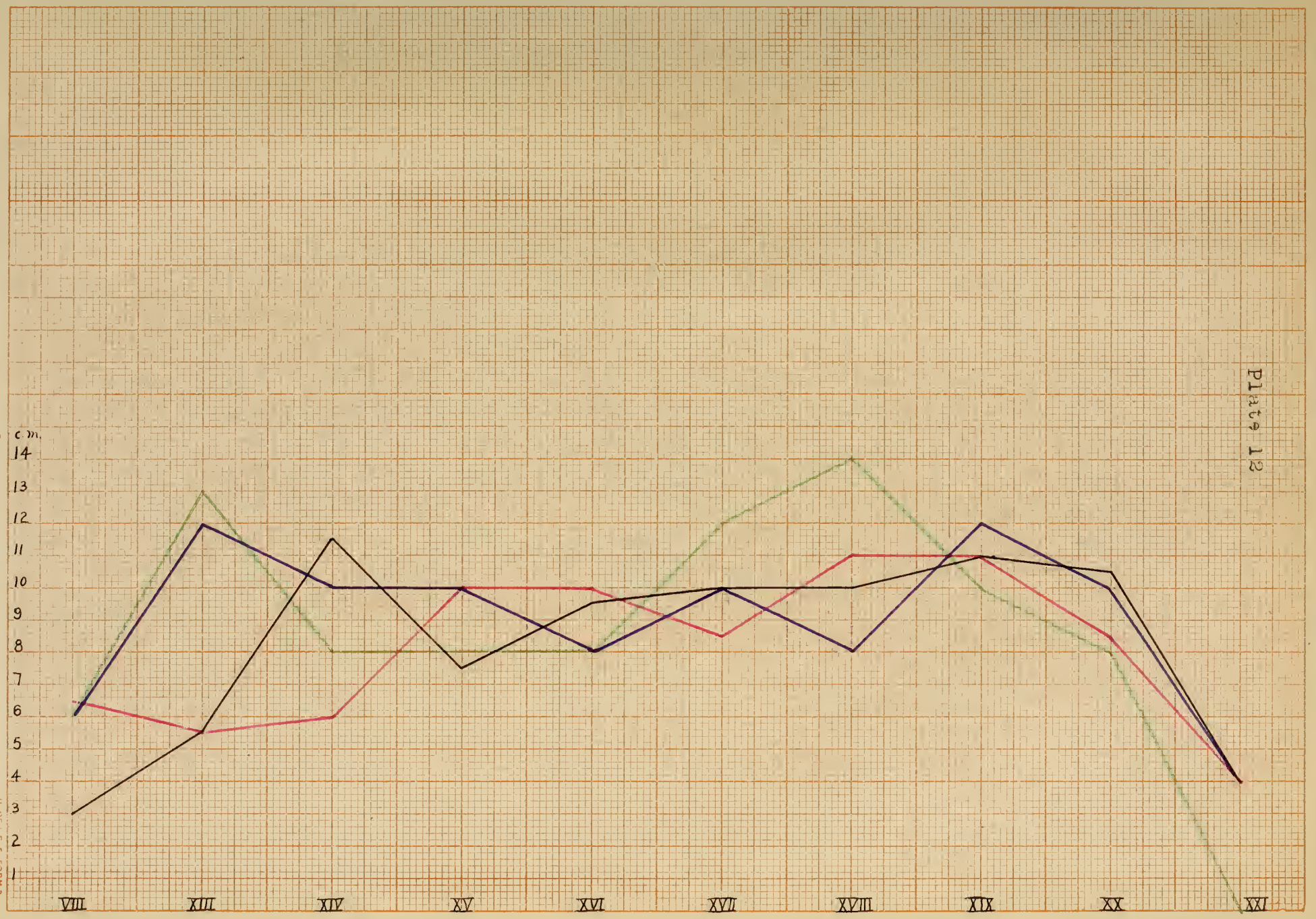
Plate 12
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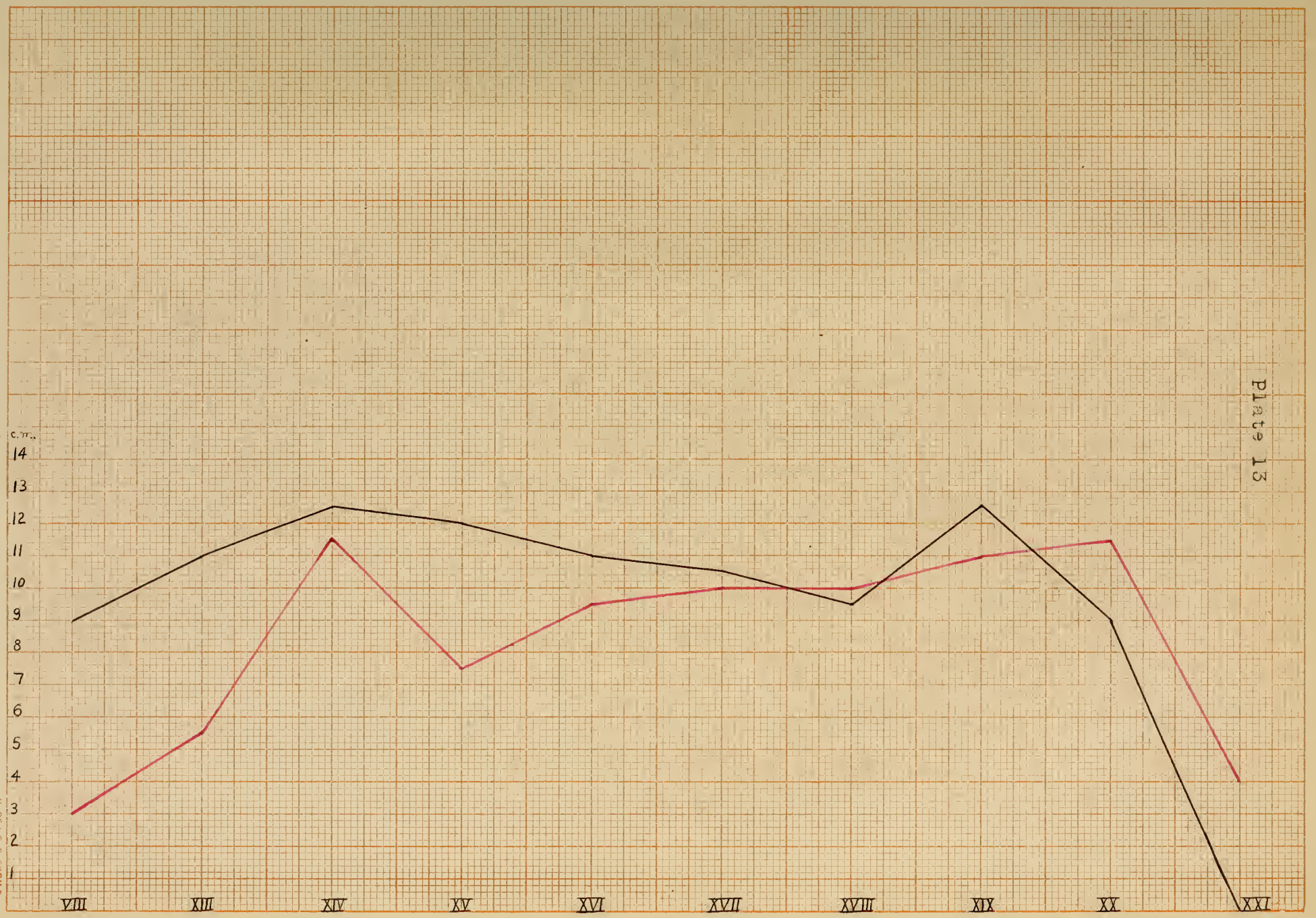
Plate 13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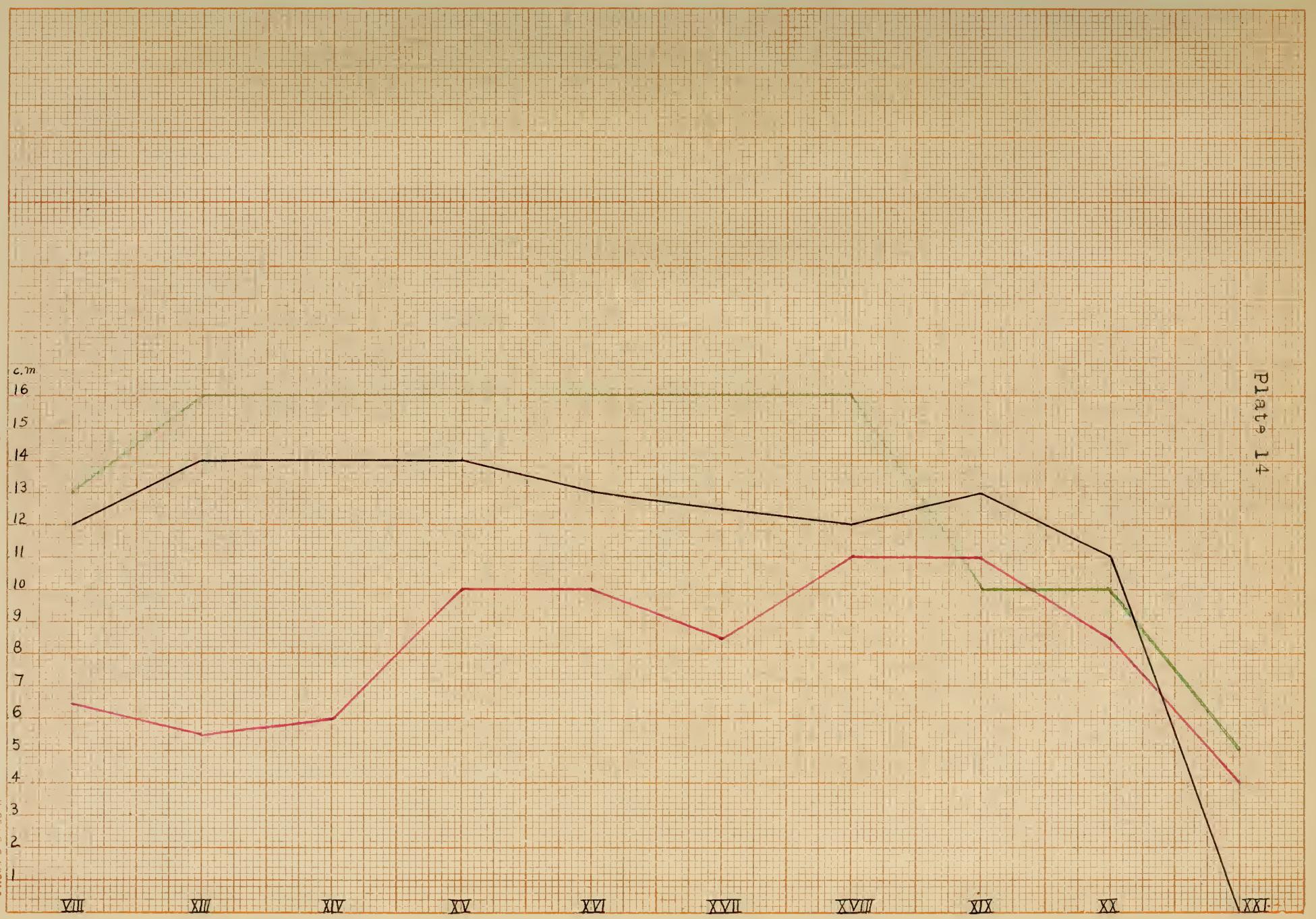
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Plate 14

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Plate 15

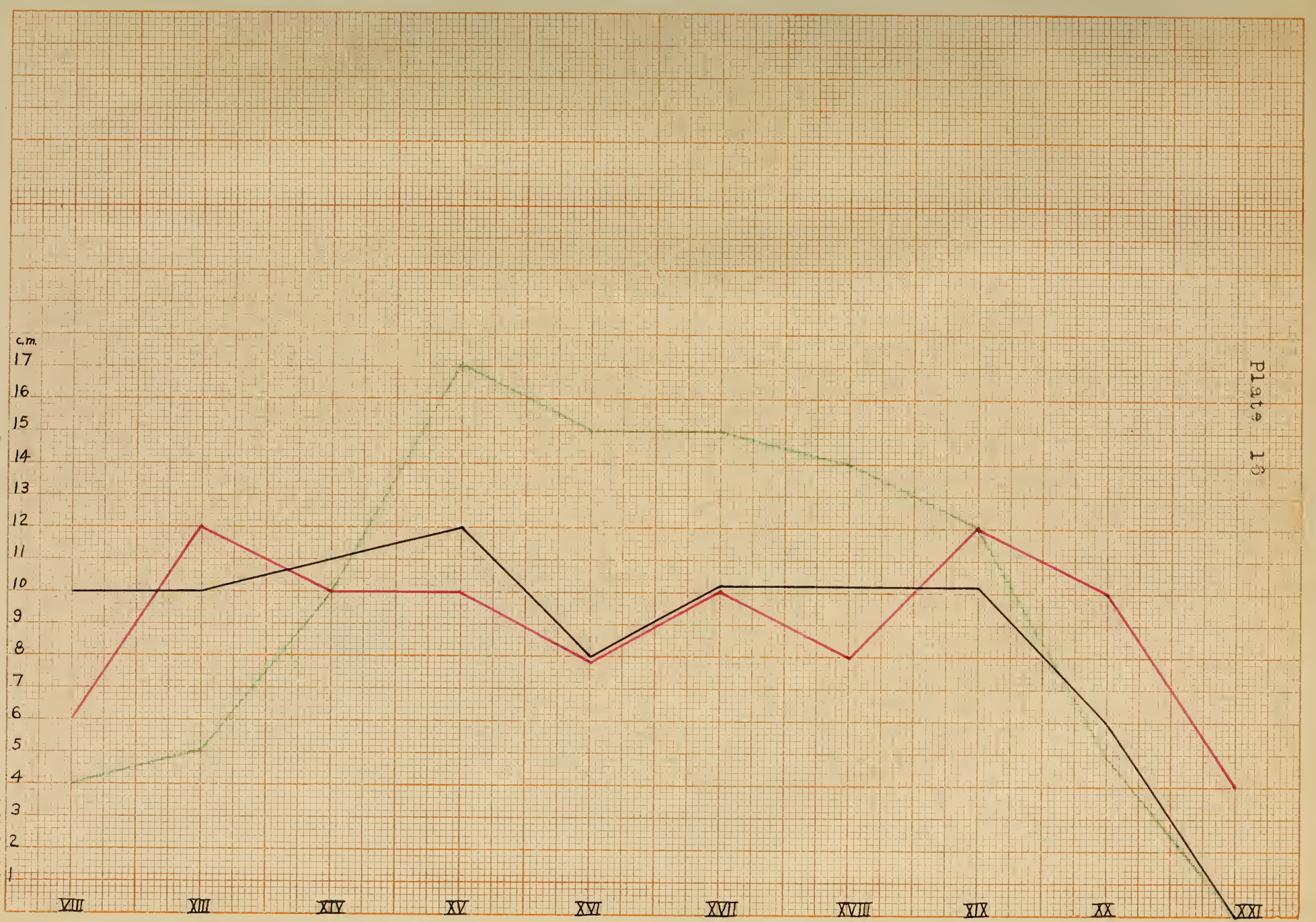

Plate 19

U. OF I. S. S. FORM 3

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